DOCUMENT RESUME

ED 436 414 SE 062 995

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TITLE	The Effects of Using the TI-92 Calculator To Enhance Junior High Students' Performance in and Attitude toward Geometry.
PUB DATE	1999-00-00
NOTE	19p.
PUB TYPE	Reports - Research (143)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Geometry; Grade 7; *Graphing Calculators; Junior High Schools; *Mathematics Instruction; *Student Attitudes

ABSTRACT

This study extended over three months and involved 344 subjects. It compared the performance and attitudes of seventh-grade students taught geometry using the TI-92 calculator and a supplementary activity manual written to be used with the TI-92 calculator with the performance and attitudes of students using the traditional approach. On a comprehensive common post study geometry examination, the students who were taught geometry using the TI-92 calculator had significantly higher scores than those taught by traditional means. The students who were taught geometry using the TI-92 calculator had a significantly more positive attitude toward the study of geometry than students taught by traditional means. (Contains 14 references.) (Author/WRM)

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The effects of using the TI-92 calculator to enhance junior high students' performance in and attitude toward geometry

Author: Walter F. Ryan

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ABSTRACT. This study extended over three months and involved 344 subjects. It compared the performance and attitude of seventh-grade students taught geometry using the TI-92 calculator and a supplementary activity manual written to be used with the TI-92 calculator, to the performance and attitude of students using the traditional approach. On a comprehensive common post study geometry examination, the students who were taught geometry using the TI-92 calculator had significantly higher scores than those taught by traditional means. The students who were taught geometry using the TI-92 calculator had a significantly more positive attitude toward the study of geometry than students taught by traditional means.

Theoretical Framework

The National Council of Teachers of Mathematics (1989) has advocated the use of calculators and computers to enhance mathematics instruction. As noted by the National Council of Teachers of Mathematics (1991), "Technology changes the nature and emphasis of the content of mathematics as well as the pedagogical strategies used to teach mathematics .... Technology — computer and calculators--saves time and, more important, give students access to powerful new ways to explore concepts at a depth that has not been possible in the past" (p. 134). The advent of The Geometer's Sketchpad (1991) and Cabri Geometry II (1994) allows students to investigate geometry ideas similar to symbolic manipulative software that permits students to explore algebraic expressions. The use of these technologies as tools of investigation enables students in geometry classes to construct diverse representations of geometry concepts.

As proposed by Dina van Hiele-Geldof and Pierre van Hiele (1986), students progress through five levels of thought as their understanding of a geometry concept develops. The five levels are Level 1 - Visualization, Level 2 - Analysis, Level 3 - Abstraction, Level 4 - Deduction, and Level 5 - Rigor. According to the van Hieles, students progress in their level of thinking of geometric concepts through involvement with appropriate experience-based geometry tasks. A learner cannot progress to a higher level of understanding of a geometry concept without mastering all lower levels. Attainment of higher levels of understanding is not dependent on age, but on the appropriate kind of geometry experiences.

Research on the effectiveness of technology in geometry has mainly focused on two computer applications, Logo and Geometric Supposer. Using Logo with elementary students has

been shown to help students make the transition from Levels 0 and 1 of the van Hiele model to Level 2 (Clements & Battista, 1989). Middle school students' work in Logo has been closely related to their level of geometric thinking in the van Hiele model (Olson, Kieren, & Ludwig, 1987). Most studies on Logo have concentrated on its facilitative effects on student understanding of geometry concepts rather than on student mastery of the geometry concepts. Research that studied achievement results using Logo in geometry classes has given mixed results. Johnson (1986) found no significant differences in achievement between experimental and control groups when investigating the use of Logo.

Geometry construction programs, such as Geometric Supposer, help students make and test geometric conjectures. Some research studies have indicated that students studying geometry with the aid of the Geometric Supposer software did better on geometry exams when compared with students who studied geometry without Geometric Supposer (Yerushalmy, Chazan, & Gordon, 1987). Other studies have indicated no significant geometry achievement gains for classes using the Geometric Supposer (Bobango, 1988).

In summary, studies on the effectiveness of using technology to enhance geometry instruction have given mixed results. However, when the learning environment and teaching approach are structured appropriately, geometry construction programs give students an avenue to manipulate geometry objects and to make and test conjectures. As noted by Clements and Battista (1992), "Perhaps, even more fundamental, inquiry environments such as the Supposer- and Logo-based environments appear to have the potential to serve as catalysts both in promoting teachers' and students' reconceptualization of what it means to learn and understand geometry and in promoting the growth of students' autonomy in mathematical thinking." (p.

454)

Purpose

The use of geometry exploratory software is increasing in mathematics classes. However, limited computer access for most mathematics classrooms diminishes the potential beneficial effects of these enriching geometry experiences. The TI-92 calculator provides similar geometry exploratory software, Cabri Geometry II (1994), at a lower cost. Since the primary users of the TI-92 calculator are mathematics teachers and students, access to the TI-92 calculators is not a problem. Therefore, a study investigating whether the use of the TI-92 calculator as an instructional tool in geometry classes increases student achievement in and attitude toward geometry was warranted. Specifically, this study investigated whether the use of the TI-92 calculator as an instructional tool

1. significantly increases student achievement in seventh-grade geometry; and
2. significantly raises seventh-grade student attitude toward the study of geometry.

Method

This study integrated the TI-92 calculator in the instructional process of the geometry section of the seventh-grade pre-algebra mathematics course in the three junior high schools of the New Albany-Floyd County School Corporation in January, February, and March of the 1997-98 academic year. In the New Albany-Floyd County School Corporation, the top 20% of seventh-grade mathematics students complete an algebra course and the remaining 80% of the seventh-grade students complete the pre-algebra course.

In preparation for the study, during the 1996-97 academic year, the TI-92 research committee explored the geometry capabilities of the TI-92 calculator and selected concepts in the geometry section of The University of Chicago School Mathematics Project Transition Mathematics (Usiskin et al, 1992), the seventh-grade pre-algebra textbook, that were suitable for exploration with the TI-92 calculator. Specifically, the geometry concepts of vertical angles, corresponding angles, alternate interior angles, properties of different quadrilaterals, the triangle sum property, area of triangles and polygons, the Pythagorean theorem, and the circumference and area of circles were chosen for the unit. Transition Mathematics uses an integrated approach to mathematics and consequently the selected geometry concepts overlaid three chapters in the textbook. This required participating teachers to agree to complete these chapters in a different sequence compared with the usual pattern used for studying these chapters.

During the summer of 1997, a supplementary manual, Seventh Grade Geometry Unit - New Albany-Floyd County School Corporation - TI-92 Supplementary Activities - Teacher Edition (Ryan, 1998), outlining specific TI-92 geometry exploratory activities to be integrated as a part of geometry lessons in the seventh-grade pre-algebra mathematics textbook was drafted. The first five of the 14 lessons in the supplementary manual familiarized students with the geometry functions on the TI-92 calculator. Therefore, the first five lessons reviewed prior geometry concepts and introduced no new geometry ideas. The remaining eight lessons complemented the study of new geometry concepts in Transition Mathematics (Usiskin et al, 1992). The suggested strategy for implementing the supplementary TI-92 activities in the seventh-grade classes was cooperative learning groups of two.

This study used an experimental-control group format to investigate the effect of the TI-92 calculator on seventh-grade student achievement in and attitude toward geometry. In the 1997-98 academic school year, the three junior high schools in the New Albany-Floyd County School Corporation had between seven and nine seventh-grade pre-algebra classes. Prior to the 1997-98 school year, administration in each junior high school randomly assigned seventh-grade pre-algebra classes to the participating teachers in the study. One seventh-grade mathematics teacher from each junior high school integrated the TI-92 exploratory, supplementary geometry activities in the selected geometry unit in two seventh-grade pre-algebra classes. The TI-92 calculator with the corresponding overhead display was available for the seventh-grade mathematics teachers in the experimental group of this study. All students in the experimental group had access to a TI-92 calculator during mathematics class. Students were not permitted to bring the TI-92 calculators home. One seventh-grade mathematics teacher from each of two of the junior high schools completed the selected geometry unit in two seventh-grade pre-algebra classes without the use of the TI-92 calculator. In the other junior high school, the teacher in the control group completed the geometry unit in three classes. Therefore, six seventh-grade pre-algebra classes were in the experimental group and seven seventh-grade pre-algebra classes were in the control group. The remaining seventh-grade pre-algebra classes in the junior high schools did not participate in the study. The sample size for the experimental group was 154 and for the control group was 190.

New Albany-Floyd County School Corporation heterogeneously groups seventh-grade students in the pre-algebra classes. Therefore, no significant difference in mathematics ability should exist between the experimental group and the control group at the beginning of this study.

However, to corroborate this assumption that no significant difference in mathematics ability existed between the two groups at the beginning of this study, a t-test was run comparing the mean scores that the participating students received in the mathematics section of the Fall 1996 Indiana's sixth-grade Indiana Statewide Testing for Educational Progress (ISTEP+). The grade six ISTEP+ allows students "to demonstrate their understanding of mathematics in a variety of ways such as using a ruler, explaining a solution, drawing a picture, or making a table or graph" (Indiana State Department of Education, 1996, p. 1). Student responses on the ISTEP+ test are graded using a rubric. "Rubrics describe the requirements for each score point level. The number of score point levels possible varies according to the requirements of each activity " (Indiana State Department of Education, 1996, p. 1). The mathematics score in the sixth-grade ISTEP+ was selected as a pretest of mathematics ability because all students in the study completed this test in the sixth grade. Additionally, this test gives a reliable indicator of student achievement in the mandated K-6 mathematics objectives for the State of Indiana.

At the end of the instructional process in the selected geometry unit, the students in the control and experimental groups completed a geometry achievement test and a geometry attitude questionnaire. The geometry achievement test had 34 questions. The questions for the test were based on the types of questions in Transition Mathematics (Usiskin et al, 1992) and were composed by two mathematics education professors and one mathematics professor. Test items were problem oriented and students had to show work to obtain full credit for the question. The test measured students' knowledge of all geometry concepts and skills taught in the geometry unit. The seventh-grade mathematics teachers did not have access to the geometry achievement test before the school testing date. Students were not permitted to use TI-92 calculators with the

geometry achievement test. All students were permitted to use a standard elementary calculator with the test.

The geometry attitude questionnaire had 20 statements. Students responded to the individual statements by choosing a preference from a five-point Likert scale. Possible answers were strongly agree, agree, no opinion, disagree, and strongly disagree. These responses were assigned values of 0, 1, 2, 3, and 4 respectively. Ten statements on the geometry attitude questionnaire were stated positively and 10 negatively. Having equal number of positive and negative statements on the geometry attitude questionnaire gives students a balanced impression of geometry. A computer answer sheet was used for the geometry attitude questionnaire and students shaded the appropriate oval on the computer answer sheet. For analysis, all statements on the geometry attitude questionnaire were changed to positive and student responses were converted accordingly. This conversion permitted the study to run one t-test to compare the two groups on their post study attitude toward geometry. Table 1 lists sample statements from the geometry attitude questionnaire.

Table 1

Sample Statements from Geometry Attitude Questionnaire

1.	Geometry is a very interesting subject.
4.	I am not able to think clearly when working Geometry problems.
11.	I approach Geometry with a feeling of confidence.
15.	Geometry helps people make sense out of the world.
18.	It is hard for me to see what Geometry is all about.
20.	I have never enjoyed working Geometry problems.

Table 2

Means and Standard Deviations of Experimental and Control Groups on the Converted Scores in Mathematics Section of the Sixth-Grade Fall 1996 ISTEP+ Test

Group	Sample Size	Mean	Standard Deviation
Experimental	154	66.25	12.86
Control	190	66.60	14.30

The maximum converted score in the ISTEP+ test was 100.

Results

Achievement Pretest

The 344 seventh-grade students involved in the study completed the ISTEP+ test in the fall of the sixth grade. The study used the score that the students obtained in the mathematics section of the ISTEP+ sixth-grade test as the dependent variable for the t-test comparing the control and experimental groups' mathematics ability prior to the geometry unit. The criterion-referenced mathematics scores on the sixth-grade ISTEP+ test range from 300 to 740. New Albany-Floyd County School Corporation converted these scores to a percentage out of 100. The converted sixth-grade ISTEP+ criterion-referenced mathematics scores were used for the analysis of the achievement pretest. The assumption of homoscedasticity, F-test significance level of 0.175, was not violated. Table 2 gives the mean mathematics composite scores and the standard deviations for both groups on the sixth-grade 1996 fall ISTEP+ test. These results gave a significance level of 0.81 for the two-tailed t-test. Thus, the analysis of the t-test results

demonstrated no significant difference in mathematics ability between the experimental and control groups prior to the geometry unit. This result suggests that both groups should be equal in mathematics ability at the beginning of the geometry unit.

Achievement Post-test

The 344 seventh-grade students involved in the study completed a post geometry achievement test. The test was criterion-referenced and thus students were permitted sufficient time to complete all questions on the test. The test consisted of 34 geometry problems and students had to show their work to obtain full credit. The total possible points on the test were 100. A grading team consisting of two mathematics education professors, a mathematics professor, and an undergraduate elementary education student constructed grading rubrics for each test question before grading the tests. Partial credit was awarded on individual problems based on the scoring rubric. The grading team graded all 344 post achievement tests. For consistency, each grader was assigned specific problems to evaluate on the test. Each grader evaluated responses on assigned problems on all completed post geometry achievement tests.

The study used the scores that the students obtained in the post geometry achievement test as the dependent variable for the t-test comparing the control and experimental groups' geometry achievement at the end of the study. The assumption of homoscedasticity, F-test significance level of 0.324, was not violated. Table 3 gives the mean scores and the standard deviations for both groups on the post geometry achievement test. These results gave a significance level of 0.006 for the two-tailed t-test. Thus, the analysis of the t-test results demonstrated that a significant difference in geometry achievement existed between the experimental and control groups at the end of the geometry unit. This result suggests that the use

Table 3

Means and Standard Deviations of Experimental and Control Groups on the Post Geometry Achievement Test

Group	Sample Size	Mean	Standard Deviation
Experimental	154	41.69	19.63
Control	190	36.10	18.20

The maximum score in the exam was 100.

of the TI-92 calculator in exploring geometry concepts was advantageous in helping students to understand these geometry concepts.

The questions in the post geometry achievement test were grouped in seven different categories: prerequisite knowledge, angles formed by intersecting lines, properties of quadrilaterals, properties of triangles, Pythagorean theorem, area, and circles. Table 4 shows the mean score obtained by the experimental and control groups in each category. The results indicated that students in the experimental group obtained considerably higher scores in the categories of prerequisite knowledge, Pythagorean theorem, area, and circles. The experimental group obtained slightly higher scores in the categories of properties of quadrilaterals and properties of triangles. The control group scored slightly better in the category of angles formed by intersecting lines. These results indicate that the use of the TI-92 calculator affects student scores positively in most geometry topics studied.

Attitude Questionnaire

The 344 seventh-grade students involved in the study completed a post geometry attitude questionnaire. The geometry attitude questionnaire had 20 statements and used a five-point

Table 4

Means of Experimental and Control Groups on Subcategories on the Post Geometry Achievement Test

Subcategory	Mean		Total Possible Points
	Experimental	Control	
Prerequisite Knowledge	7.74	6.64	10
Angles/Lines	7.46	7.74	18
Quadrilateral Properties	4.81	4.45	08
Triangle Properties	2.96	2.65	10
Pythagorean Theorem	4.26	2.51	14
Area	7.20	6.03	22
Circles	7.08	6.01	18

Likert scale of strongly agree, agree, no opinion, disagree, and strongly disagree. Ten of the statements on the geometry attitude questionnaire were stated positively and 10 negatively. For analysis, all statements on the geometry attitude questionnaire were changed to positive and student responses were converted accordingly. For example, question 4 "I am not able to think clearly when working Geometry problems" is rephrased to read "I am able to think clearly when working Geometry problems" and a student response of 4 is changed to a 0 and a 0 to a 4, a student response of 3 to a 1 and a 1 to a 3, and a student response of 2 remains a 2.

The study used the sum of the individual ratings that the students marked on the post geometry attitude questionnaire as the dependent variable for the t-test comparing the control

Table 5

Mean and Standard Deviation of the Sum of the Individual Statements of Experimental and Control Groups in the Post Geometry Attitude Questionnaire

Group	Sample Size	Number Incomplete	Number Analyzed	Mean - Sum of Statements	Standard Deviation of Sum Total
Experimental	154	10	144	32.53	14.74
Control	190	02	188	42.94	14.84

The maximum sum of statement responses was 80. The lower the sum of statement responses the more positive the response.

and experimental groups' geometry attitude at the end of the study. The assumption of homoscedasticity, F-test significance level of 0.94, was not violated. Table 5 gives the mean and the standard deviations on the sum of the ratings on the individual statements on the post geometry attitude questionnaire for both groups. These results gave a significance level for the two-tailed t-test of 8.08×10^{-10}. Thus, the analysis of the t-test results demonstrated that a significant difference in attitude toward geometry existed between the experimental and control groups at the end of the geometry unit. Additional analysis demonstrated that the experimental group was more positive on all items on the geometry questionnaire compared with the control group. In particular, the experimental group and the control groups had the largest difference in attitude on the statements "I do not like Geometry," with a difference in average student rating of 0.87 and "Geometry is fun," with a difference in average student rating of 0.80. The experimental group had the highest average positive student ratings for the statements "When I think about Geometry, I get depressed," with a rating of 2.81 and "I doubt I will ever understand

Geometry very well," with a rating of 2.79. In other words, the experimental group strongly disagreed with these statements. These results suggested that using the TI-92 calculator as an aid to teach junior high geometry help create a very positive attitude toward geometry study.

Discussion

Results obtained in this study indicated that junior high students who use the TI-92 calculator as an aid in studying geometry had significantly higher geometry test scores and significantly higher positive attitude toward geometry than the junior high students who did not use the TI-92 calculator as an aid in studying geometry. A pretest of mathematics achievement indicated that both groups were not significantly different in mathematics achievement at the beginning of the study. The students in the experimental group were aware of their participation in the experiment, and so the Hawthorne effect cannot be ruled out as a contributing factor to the higher scores in geometry achievement obtained by the experimental group and the experimental group's more positive attitude toward geometry. The post geometry achievement test should not be biased toward either group since the examination was constructed by university professors, and no teachers, experimental or control, saw the examination before the testing date. Both experimental and control groups used the same textbook, The University of Chicago School Mathematics Project Transition Mathematics (Usiskin et al, 1992), and completed the same sections in this textbook. However, the experimental group had the supplementary manual, Seventh Grade Geometry Unit - New Albany-Floyd County School Corporation - TI-92 Supplementary Activities - Teacher Edition (Ryan, 1998), and this supplementary unit contained additional practice problems that may have had an added positive influence in the geometry achievement. The fact that different teachers taught various groups raises the possibility that the

effects of increased geometry achievement and more positive attitude were due to the teachers rather than the treatment.

This study did not attempt to determine what factors contributed to the more positive attitude in the experimental group. The novelty of using the TI-92 calculator, more cooperative group work, or the ability to visualize geometry problems on the TI-92 may be some factors that affected student attitude. Future studies should try to determine whether continued use of the TI-92 calculator over a prolonged period of time has the same positive influence on student attitude toward geometry.

It is not clear what really caused the higher scores in achievement when geometry software of the TI-92 calculator was used. Several factors may be helping. For example, the visual images supplied by the calculator may help students internalize the concept, the active manipulation of the geometry diagrams may engage students more in the geometry investigations, or the immediate feedback and the ability to check problem solutions may encourage students to stay on a task longer. Future studies should try to discern the relative contribution of individual factors to the increase in achievement.

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